ISSN: 2230-9926

Available online at http://www.journalijdr.com

IJDR

International Journal of Development Research
Vol. 08, Issue, 05, pp.20332-20338, May, 2018

ORIGINAL RESEARCH ARTICLE

OPEN ACCESS

EVALUATION OF FRACTURE RESISTANCE AND FAILUREMODEOF THIN-WALLED ROOTS RESTORED WITH DIFFERENT POST SYSTEMS

***[1]Luís Gustavo Nunes Dias de Pinho, [1]Iandara Schettert Silva, [2]Tulio Marcos Kalife Coelho and[1]Gustavo Helder Vinholi**

[1]Program in Health and Development in the Mid-West Region FAMED / UFMS – Cidade Universitária – Pioneiros, Campo Grande 79070-900, Mato Grosso do Sul, Brazil

[2]Departmentof Dental Prothesis FAODO/UFMS-Cidade Universitária –Pioneiros, Campo Grande 79070-900, Mato Grosso do Sul, Brazil

ARTICLE INFO

Article History:

Received 12th February, 2018
Received in revised form
29th March, 2018
Accepted 14th April, 2018
Published online 28th May, 2018

Key Words:

Remaining roots,
Fracture strength, failure mode,
Cast postand core,
Fiberglass post, resin cement,
Glass ionomer.

****Corresponding author:***
Luís Gustavo Nunes Dias de Pinho,
Program in Health andDevelopment in theMid-West Region FAMED / UFMS – Cidade Universitária –Pioneiros, Campo Grande 79070-900, Mato Grosso do Sul, Brazil.

ABSTRACT

The objective of this manuscript was to evaluate the fracture resistance and failure mode of roots of bovine incisors with the root canal purposely enlarged, reinforced with different restorative materials and compared with intact roots restored with cast post and core. In this manuscript 75 bovine inferior central incisors were selected, being sectioned transversally and leaving only 14 mm of root. A standardized wear sequence was used to make them fragile, leaving the remaining walls with 0.5 to 0.7 mm thick in the cervical edge. In the control group (RI) the remaining walls had 2.0 to 2.5 mm thickness at the cervical edge and were restored with cast post and core. All samples received a total metallic crown. From the four experimental groups (n = 15), one group did not received internal root reinforcement (SR) and the other three were tested for composite resin (RC) or glass ionomer cement (CIV) reinforcements associated with cast post and core or composite resin in association with fiberglass post (PFV). The tests were applied in a universal test machine (Instron) with tangential compression loading, focusing on the palatal side of the crown, forming an angle of 135° with the long axis of the root, at a speed of 1 mm / min. The force average values obtained were 330.45 N; 218.58 N; 186.54 N; 275.44 N and 295.10 N for the groups RC Group, PFV Group, Group IV, SR Group and RI Group. Among the RC, SR and RI groups there was no statistical difference for the obtained average forces. The PFV and IV groups differ statistically from the mean force obtained in relation to the RC, SR and RI groups ($P < 0.05$). However PFV and IV are statistically similar. In the PFV and IV groups, there was a higher incidence of favorable fractures, while in the other groups non-favorable fractures prevailed. Reinforcing internally a fragile root with composite resin favors the increase of fracture resistance. A greater amount of remaining dentin was responsible for a greater fracture resistance, but without statistical difference in comparison with weakened roots without reinforcement. Restored fragile roots with PFV associated to the composite resin (anatomical post) have the advantage of having favorable fractures, allowing the reuse of the root.On the other hand, when working with cast post and core we normally reach an increase in resistance, but a large incidence of non-favorable fractures is present.

Citation: Luís Gustavo Nunes Dias de Pinho, Iandara Schettert Silva, Tulio Marcos Kalife Coelho and Gustavo Helder Vinholi, 2018. "Evaluation of fracture resistance and failuremodeof thin-walled roots restored with different post systems", *International Journal of Development Research*, 8, (05), 20332-20338.

INTRODUCTION

Teeth endodontically treated with great structural loss need intra-canal retainers for their rehabilitation. Traditionally one of the most used biomaterials for this function is the cast post and core (Mitsui *et al.,* 2004,Özcan andValandro 2009; Faria *et al.,* 2011). This component, because it is rigid, resists forces without distortion, but it transmits tensions to the root dentin (Fernandes and Dessai 2001). The difference of the modulus of elasticity of this type of retainer and dentin is an aggravating factor for the concentration of stress in the root structures (Ferrari *et al.,* 2000,Torabi and Fattahi 2009). As the amount of remaining dentin can influence fracture resistance, root canal dentin must be preserved to the maximum extent possible during preparation of the root canal (Zogheib *et al.,* 2008, Mireku *et al.,* 2010, Mattos *et al.,* 2012, Fragou *et al.,* 2012, Zhou and Wang 2013, Zicari *et al.,* 2013). The possibility of root fracture increases in cases where the cervical diameter of the root canal is too broad (Sirimai *et al.,* 1999, Delfino and Nagle 2003). Due to the large number of options that have been proposed, the choices regarding the selection of materials and techniques to restore root canals with weakened walls become difficult (Ayad *et al.,* 2010). However, the search is basedon mechanical properties similar to the remaining dental structure as well as a correct selection of the cementation system. (Xiong *et al.,* 2015, Gomes *et al.,* 2015, Gomes *et al.,* 2016).One of the options would be to reinforce the root walls and restore the inner diameter of the canal as close to normal before cementing an intra-radicular post, which favors the dissipation of forces and protects the remaining root (Theodosopoulou and Chochlidakis 2009, Laxe *et al.,* 2009, Balkaya *et al.,* 2013, Ferro *et al.,* 2016). Several studies corroborate the idea that internally reinforcing the brittle roots can considerably increase fracture resistance (Liang *et al.,* 2007, Wu *et al* 2007, Torres-Sánches *et al.,* 2013, Balkaya and Birdal2013). In addition to the studies to apply filling materials, new techniques were also developed, among them the anatomical post. The fiberglass post is wrapped by composite resin modeled inside the root canal, which allows a thin layer of cement at the post / root interface, improving retention and mechanical properties (Grandini *et al.,* 2003, Clavijo *et al.,* 2006,Albashaireh *et al.,* 2009, Özdemir *et al.* 2012, Gomes *et al.,* 2016,Cardenas *et al.,* 2016, Amaral *et al.,* 2015). In view of the above, this manuscript proposes to evaluate the fracture resistance of fragile radicular remnants by means of different techniques: fiberglass posts associated with photopolymerizable composite resins and cast post and cores associated or not with the use of root reinforcement (photopolymerizable resin or glass ionomer), besides evaluating the failuremode presented by the root, classified in favorable or non-favorable fractures.

MATERIALS AND METHODS

Selected samples

In this paper were selected 75 bovine inferior central incisors, free of cavities or fractures. Its roots were sectioned with a diamond disc (KG Sorensen, Brazil) in low rotation, remaining standardized in the length of 14 mm (measurement performed with a digital pachymeter). The sectioned roots were submitted to endodontic treatment. Instrumentation with K-filesize 80 (Dentsply Maillefer, Brazil) and obturation using gutta-percha (Tanari, Brazil) using the lateral condensation technique, remaining 1 mm short of the root apex. The gutta-percha removal was performed up to 9 mm deep (maintained 4 mm apical seal) with a Largo bur No. 4 (Injecta, Brazil), maintained between 2.0 and 2.5 mm thick root wall at the edge assessment with digital pachymeter.

Intra-root preparation for similar weakened roots

Of the 75 teeth, 15 samples formed the control group (n = 15) with intact roots with radicular dentinal remnant with a thickness of 2.0 to 2.5 mm in the cervical edge. On the other hand, 60 samples that had the fragilized roots were randomly distributed into four groups, according to the intra-radicular restorative materials. The 60 teeth suffered additional wear on the walls of the root canal, in order to simulate roots with weakened walls. A No. 5 Largo bur (Injecta, Brazil) was introduced into the root canal at low rotation up to 9 mm deep. A spherical diamond drill No. 1016 (KG Sorensen, Brazil - 1.8 mm diameter) was used at high speed, under constant water cooling to 8 mm depth. After the procedure described above, a 2.5 mm diameter spherical diamond drill No. 3017 HL (KG Sorensen, Brazil) performed wear on the middle third until it reached 5 mm depth. Finally, a spherical diamond drill No. 3018 (KG Sorensen, Brazil) performed wear up to 3 mm deep to prepare the third cervical. The remainder at the cervical border at the end of the preparation had a thickness between 0.50 and 0.70 mm in a simulation of a root weakened by excess structural loss (Figures 1).

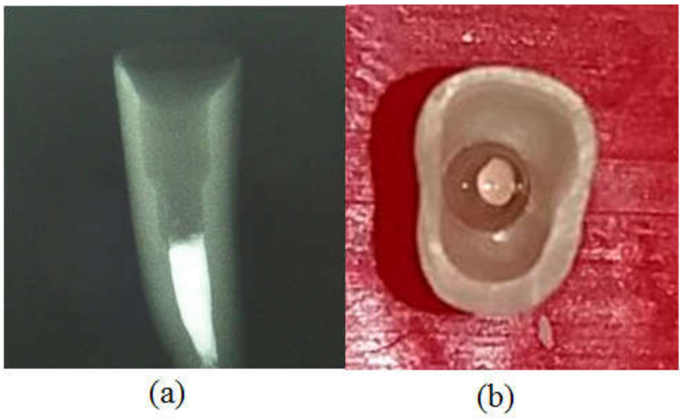


Figure 1. (a) X-rayshowing a weakenedroot , (b) Occlusalviewshowing de cervical edge

Group with restored intact roots with cast post and core (RI)

The root canal was modeled using Pinjet prefabricated acrylic pins (Angelus, Brazil) associated with the Duralay chemical dam resin (Reliance Dental, USA). The coronary part of the pin was made with the same resin. To standardize the preparation of the coronary portion in all groups, a duralay resin model (Reliance Dental, USA) was used with five replicates obtained from the mold of an upper central incisor prepared to receive a total crown that was then cast in Co-Cr (Fitcast cobalt, Talmax, Brazil). EVA - Ethylene / Vinyl Acetate copolymer (FGM, Brazil) matrices were made in a vacuum plastic laminating machine, which served as a guide in the modeling of the cast and post coronary portion. The pin was cast in Co-Cr and cemented with U-200 resin cement (3M - Brazil) after conditioning the root canal with 37% phosphoric acid (Condac37 - FGM, Brazil) for 10 seconds and washing abundantly with water and then dried with jets and absorbent paper tips.

Group with restored weakened roots with cast post and core and reinforced with composite resin (RC)

Subsequent to the conditioning of the root canal with 37% phosphoric acid (Condac37 - FGM, Brazil) for 10 seconds and washing abundant with water and subsequently dried with air jets and absorbent paper tips, the Universal Single Bond adhesive (3M ESPE) was applied, being spread with light air jets and in the polymerized sequence for 60 seconds. The modeling of the weakened root was performed filling the walls of the root canal with composite resin (Z 350 3M ESPE). Each layer was photopolymerized with the aid of a fiberglass pin for 90 seconds (White post n ° 2, FGM - Brazil). After finalization of the reinforcement, the formed root canal was reprepared so that the remaining walls were 2.0 to 2.5 mm thick, measured with a digital caliper (Figure 2). Then an acrylic pattern for casting was obtained, following the same technique used in the group with intact roots. The pin was cast in Co-Cr (Fitcast Cobalto, Talmax, Brazil) and cemented with U-200 Resin cement (3M - Brazil).

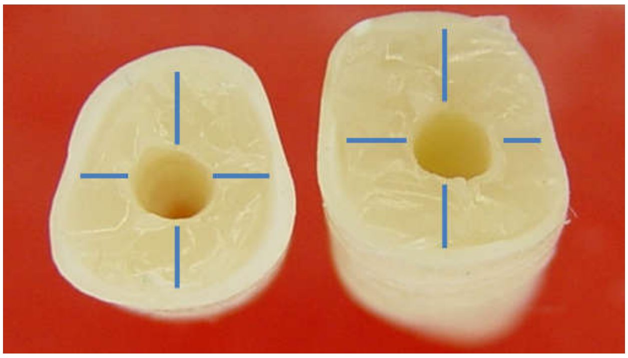


Figure 2. Root reforced with compositeresin

Group with restored weakened roots with cast post and core and reinforced with glass ionomer (IV)

The weakened roots, after conditioning the root canal with 37% phosphoric acid for 10 seconds, and abundant flushing with water and subsequently dried with air jets and absorbent paper tips, were filled with self-cure glass ionomer cement (Riva self cure, SDI - Australia), which was introduced into the root canal using a Centrix syringe (New DFL, Brazil). The channel modeling was performed with the help of a fiberglass pin (White post n ° 2, FGM - Brazil) with solid petroleum jelly applied on its surface to a depth of 9 mm held centrally until the total cement prey (Figure 3).The formed root canal was reprepared so that the remaining walls were 2.0 to 2.5mm thick.With the completion of the preparation of the root canal, an acrylic pattern for casting was obtained, following the same technique used in the group with intact roots. It was then cast in Co-Cr and cemented with U-200 Resin cement.

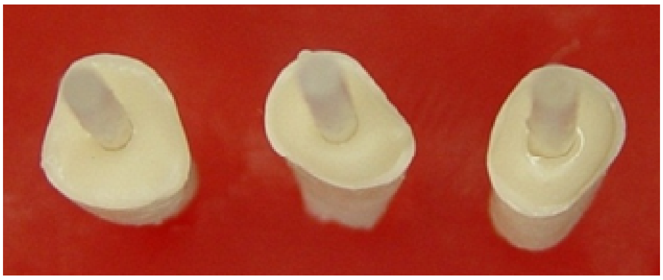


Figure 3. Root reforced with self-cure glass ionomer cement

Group with restored weakened roots with fiberglass post and reinforced with composite resin (PFV)

Fiberglass post n° 2 (FGM) had its length cut at 12.0 mm (9.0 mm inside the root canal and 3.0 mm to support the filling core), being conditioned with 37% phosphoric acid (Condac 37, FGM, Brazil). Then a single component silane layer (Prosil, FGM, Brazil) was applied on the post, and after the volatilization the resin adhesive was applied (Single Bond universal - 3M) followed by photoplimerization for 20 seconds. An increment of composite resin (Z350, 3M ESPE) was applied on the post. In addition, the post / resin assembly was accommodated in the root canal (previously isolated with water based lubricant - Ky gel, Johnson and Johnson - Brazil), at 9 mm depth, which was then removed. Similar to the interior of the root canal, the composite resin was polymerized for 20 seconds on each face. In the coronal remainder of the fiberglass post (3 mm), increments of composite resin were added for the realization of the coronary part of the retainer using as template the EVA matrices previously obtained through the metallic standards. The anatomic posts were cemented with resin cement U200 (3M ESPE) after conditioning the root canal with 37% phosphoric acid (Condac37 - FGM, Brazil) for 10 seconds and washing abundantly with water and subsequently dried with air jets and absorbent paper tips .

Group with weakened roots without reinforcement (SR)

The weakened roots of this group did not receive any type of root reinforcement. An cast post and core was obtained by the same technique used in the group with intact roots, in which they were cemented with resin cement U200 (3M ESPE) after conditioning the root canal with 37% phosphoric acid (Condac37 - FGM, Brazil) for 10 seconds and washing abundantly with water and subsequently dried with air jets and absorbent paper tips.

Preparation of the test specimens

After the cementation procedure of all the posts of the five groups, metallic crowns were obtained following the same technique of standardization of the coronary part of the posts, and then cemented with cement U-200. The roots received a thin layer of wax n ° 7 on its surface to allow space for the simulation of the periodontal ligament. Colorless, self-polymerizable acrylic resin (JET, Clássico, Brazil) was poured into the half-inch PVC (Tigre do Brasil) 20 mm high cylinders. The teeth were immersed in the resin, centralized, keeping 3 mm of root away from the resin to simulate the biological distance. After the resin prey, the teeth were removed and received hot water bath for total removal of the wax. Afterwards, fluid addition silicone (Variotime - HeraeusKulzer, Germany) was applied inside the resin in the pvc cylinder (space formed by the insertion of the root) and the teeth were repositioned, thus forming a fluid silicone layer simulating the periodontal ligament.

Fracture strength test

For this test the samples were placed in a metal support with a slope of 45 ° in relation to the base, to allow the application of a load with a 135 ° angle with the axis of the tooth (similar to the angle formed between upper and lower incisors in normal occlusion). Subsequently a tangential compression force was applied on a Universal Testing Machine (INSTRON) at a speed of 1 mm / min until the fracture occurred. The fracture resistance data of the root remainder were analyzed by ANOVA and Tukey's test. The statistical significance level was 5% and the statistical calculation was performed in the SPSS 20 program (SPSS Inc., Chicago, IL, USA).

Failure mode

All teeth samples were submitted to digital radiographic evaluation in the Xtreme II/Bruker machine of the Laboratory of Experimental Carcinogenesis of the PPGSD/UFMS, before and after the fracture strength test. Thus, it is possible to evaluate the characteristic of the fracture propensity of each group, classified in favorable or non-favorable fractures.

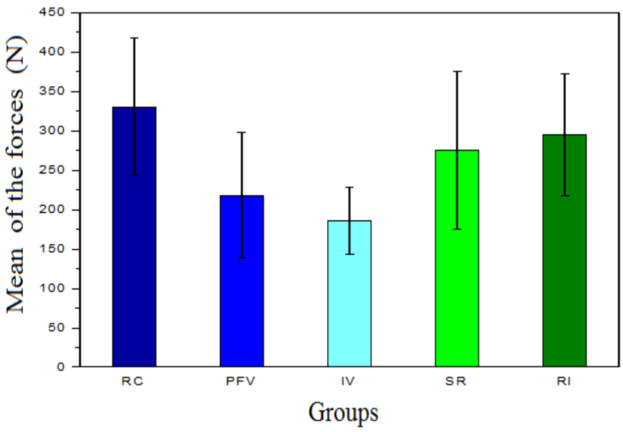
Table 1. Statistical difference between groups

RC	PFV	IV	SR	RI
330.45 ± 86.97 A	218.58 ± 80.21 B	186.54 ± 42.68 B	275.44 ± 100.65 A	195.10 ± 77.59 A

RESULTS

Resistance to fracture

Graph 1 shows the mean values ± standard deviation for the forces obtained in each of the evaluated groups. The averages obtained were 330.45 ± 86.97 (N); 218.58 ± 80.21 (N); 186.54 ± 42.68 (N); 275.44 ± 100.65 (N) and 295.10 ± 77.59 (N) for the RC, PFV, IV, SR and RI groups. The maximum strength values for the RC, PFV, IV, SR and RI groups were 525.02 N; 359.32 N; 269.82 N; 508.23 and 455.99 N, and the minimum values were 191.20 N, 120.39 N; 118.31 N; 88.02 and 151.53 N.

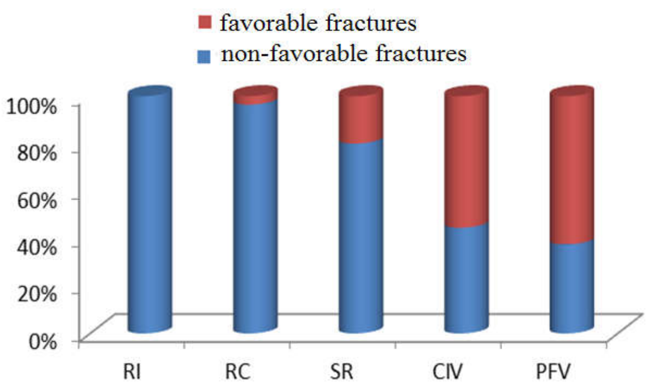


Graphic 1 . Mean ± standard deviation for the forces obtained in each of the groups evaluated

Statistical analysis showed that for the RC, SR and RI groups there is no statistical difference for the mean forces obtained on the basis of the p-value between the pairs ($p > 0.05$). On the other hand, the PFV and IV groups differ statistically from the mean strength obtained in relation to the RC, SR and RI groups ($P < 0.05$). However, the groups PFV and IV are statistically similar (Table 1).

Failure mode

Graph 2 shows the prevalence of favorable and non-favorable fractures of the groups studied in this manuscript.



Graphic2. Prevalence of favorable and non-favorable fractures of the groups studied in this manuscript

DISCUSSION

The comparison of the mean values obtained with the use of cast post and core (except for the glass ionomer reinforced group) in relation to the mean value obtained with the use of an anatomic post, shows that the results are in accordance with those studies that demonstrated higher values of Fracture strength for cast post and corethan for resin-associated fiberglass posts (Giovani *et al.,* 2009, Torabi and Fattahi 2009). Results obtained can be explained by the fact that the roots do not have coronary remnants, being quite common the fracture associated with the failure of union of the resin with the surface of the post, remaining the root portion intact. Some studies have demonstrated the need for a satisfactory coronary remnant and ferrule preparation when working with fiberglass post (Fragou *et al.,* 2012, Zhou and Wang 2013;Zicari *et al.,* 2013).

However, other studies affirm that cast post and core is more indicated when there is no coronary remnant (Özcan and Valandro 2009; Faria *et al.,* 2011;Resende *et al.,* 2017). According to the study by Fukui *et al.* (2009), the group that used cast post and coreand composite resin reinforcing the canal had better mechanical properties in the rehabilitation of compromised roots, a fact also observed by Balkaya and Birdal (2013), who affirmed that internally reinforcing a weakened root with resin is an effective technique.This trend was also demonstrated in our study, that is, the resistance was slightly higher, but did not represent statistical significance, contrary to the work of Liang *et al.* (2007), where by strengthening the root internally with resin, the fracture resistance practically doubled with the use of cast post and core. The results obtained from this study corroborated with a trend widely reported in the literature, a non-favorable root fracture when working with a cast post and core (Martinez – Insua *et al.,* 1998, Marchionatti *et al.,* 2017, Gehrcke *et al.,* 2017, Varvara *et al.,* (2007), Torabi and Fattahi 2009, Jain and Vinayak 2011, Li *et al.,* 2011;Balkaya and Birdal 2013, Torres-Sánches *et al.,* 2013).

In the RC group, there was 93.3% of this type of fracture (Figure 4), only one sample suffered the displacement of the pin not fracturing the root, whereas the RI group presented 100% catastrophic fractures (Figures5a,5b), remaining the same pattern (fracture of the middle third of the root, affecting the vestibular face). In the SR group there were 75% of non-favorable fractures (Figure 6a), 05 retainers were dislodged without root fracture (Figure 6b), this is probably associated with the conical conformation of the retainer, which hinders its retention inside the root canal, favoring its dislocation. However, only the CIV group had a predominance of favorable fractures. The results obtained in our study corroborated with the results of Wu *et al.,* (2007), which demonstrated that when the root is internally reinforced with composite RC before the preparation of cast post and core, the fracture resistance is much higher than when reinforcing with glass ionomer. Analyzing the test specimens after the test was demonstrated that with glass ionomer, the most frequent faults were fracture / fragmentation of the reinforcement or the decimentation of the retainer (Figure 7a), characterizing, thus, favorable fractures (09 samples).

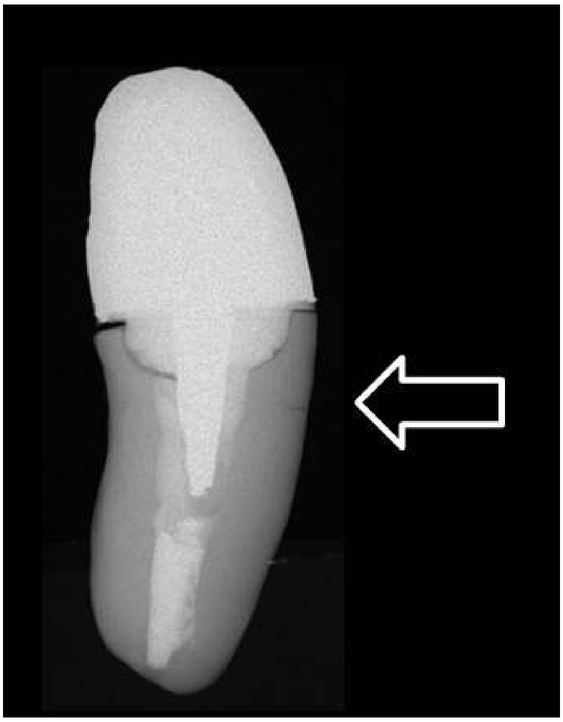


Figure 4. Fracture of the middle third of the root reinforced with compositeresin

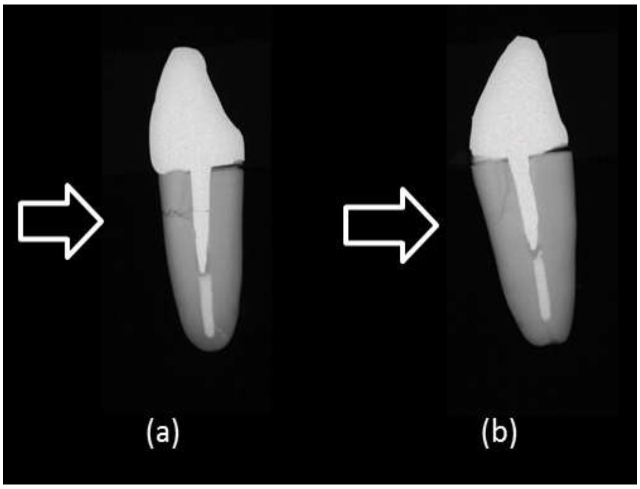


Figure 5. (a) Fractureofthe pin andthemiddlethirdofthe non-weakened root, (b) Fractureonlyofthemiddlethirdofthe non-weakened root

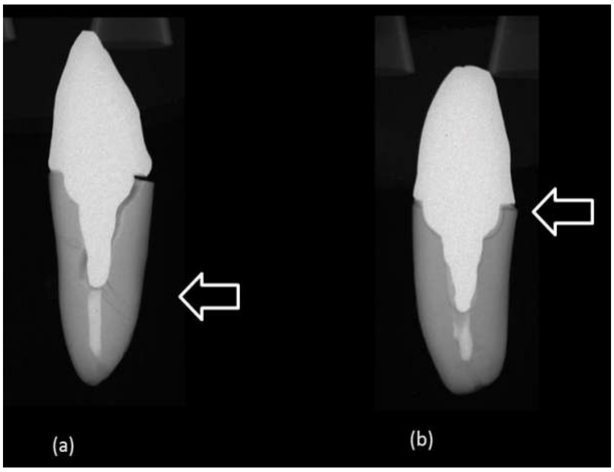


Figure 6. (a) Non-favorablefracture(b) Retainer dislodged without root fracture

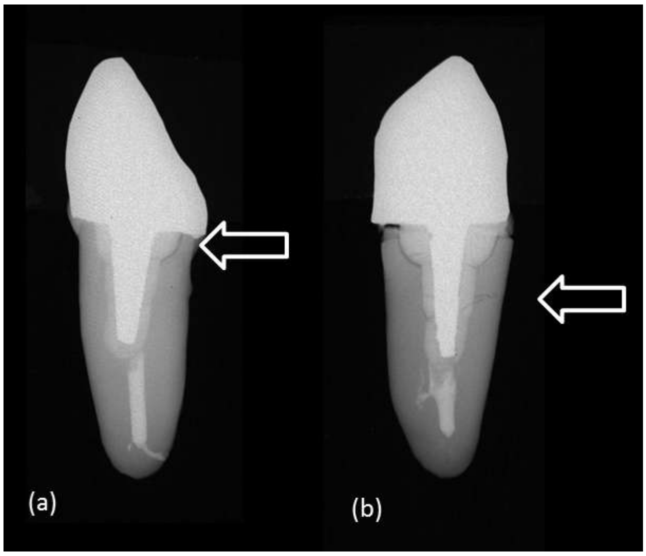


Figure 7. (a) Favorablefracture, bondfailure(b) Non-favorablefracture

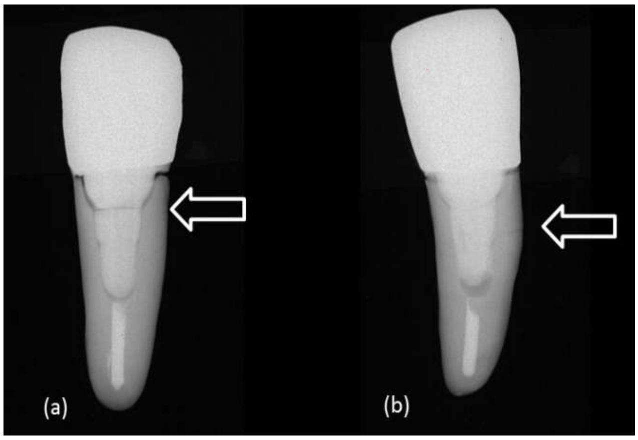


Figure 8. (a) Favorablefracture, affectingonlythe post(b) Non-favorablefracture

Only 40% (06 samples) had root involvement, causing non-favorable fractures (Figure 7b). Thus, in spite of the low fracture resistance, the reinforcement with glass ionomer proved to be interesting because it provides root reuse in 60% of the cases. The intact roots with cast post and core had an average resistance slightly superior to the fragilized roots that did not recieved internal reinforcement before the retainer cimentation, but without statistical significance, thus agreeing with the work of K1vanç *et al*. (2009), who identified that a greater amount of remaining dentin resulted in a slightly higher resistance, but not being statistically significant. From the use of the Anatomical post (PFV), a behavior widely supported by the literature was observed, that is, the presence of favorable fractures; (Santos *et al.,* 2010), which is associated with the fracture of the cervical third of the root, the post or the resin responsible for the coronary filling (Teixeira *et al.,* 2005, Torres-Sánches *et al.,* al., 2011, Silva *et al.,* 2011, Balkaya and Birdal 2013, AlQahtani *et al.,* 2017, Gehrcke *et al.,* 2017). Of the 15 samples, 10 of them (66%) presented fractures only in the post or reinforcing resin associated to the post (Figure 8a), either in the coronary or radicular part. In the other 05 samples the fracture affected the post and also the root structure, being classified as non-favorable (Figure 8b). It is interesting to note that the results obtained in this manuscript should be interpreted carefully, taking into account the natural limitations presented by a laboratory test.

Conclusion

Reinforcing internally a weakened root with composite resin favors the increase of fracture resistance, as opposed to reinforcing with glass ionomer cement, which presented the least resistance among all groups tested. In this manuscript, it was observed that a greater amount of remaining dentin was responsible for as light y higher fracture resistance, but without statistical difference in comparison with weakened roots without reinforcement. Restored weakened roots with fiberglass post associated to the composite resin (anatomical post), although presenting a lower fracture resistance when compared to most groups restored with cast post and core, have the advantage of having favorable fractures, allowing the reuse of the root. On the other hand, when using cast post and core we normally reach an increase in resistance, but a large incidence of catastrophic fractures is present.

REFERENCES

Albashaireh, ZS., Ghazal, M. and Kern, M. 2010. Effects of endodontic post surface treatment, dentin conditioning, and artificial aging on the retention of glass fiber-reinforced composite resin posts. *J Prosthet Dent.,* 103:31-39.

AlQahtani, A., Albargash, A., Abduljabbar, T., Bahmmam, F., AbGhani, SM., Nassem, M. *et al.* 2017. Fracture resistance of maxillary lateral incisors restored with different post systems. *J Biomater Tissue Eng.,* 7:1-5.

Amaral, FR., Jassé, FF., Calixto, LR., da Silva Junior, JE., Neto, CS., de Andrade MF, *et al.* 2015. Direct anatomical post for weakened roots:The state of knowledge. *Sci J Dent.,* 2:13-20.

Ayad, MF., Bahannan, AS. and Rosentiel, SF. 2010. Morphological Characteristics of the interface between resin composite and glass-ionomer cement to thin-walled roots: A microscopic investigation. *Am J Dent.,* 23(2):103-107.

Balkaya, MC. and BirdalI, S. 2013. Effect of resin-based materials on fracture resistance of endodontically treated thin-walled teeth. *J Prosthet Dent.,* 109:296-303.

Cardenas, AFM., Siqueira, FSF., Davila-Sanchez, A., Gomes, GM., Reis, A. and Gomes, JC. 2016. Four-year follow-up ofdirectanatomicalfiber post andesthetic procedures: A case report. *Operative Dentistry.,* 41(4):363-369.

Clavijo, VGR., Souza NC de, Andrade MF de and Susin AH. 2006. Pinos Anatômicos uma nova perspectiva clínica. *Dental Press Estét.,* jul/ago/set;3(3):110-130.

Delfino, CS. and Nagle, MM. 2003. Utilização do sistema Luminex para reforço de raízes fragilizadas. RBO. mai/jun;60(3):196-199.

Faria, ACL., Rodrigues, RCS., Antunes, RPA., Mattos, MGC de and Ribeiro, RF. 2011. Endodontically treated teeth: Characteristics and considerations to restore them. *Journal of Prosthodontic Research*, 55:69-74.

Fernandes, AS. and Dessai, GS. 2001. Factors Affecting the fracture resistance of post-core reconstructed teeth: A review. *Int J Prosthodont.,* 14(4):355-363.

Ferrari, M., Vichi, A. and García-Godoy, F. 2000. Clinical evaluation of fiber-reinforced epoxy resin posts and cast post and cores. *Am J Dent.,* may;13:15B-18B.

Ferro MC de L, Colucci, V., Marques, AG., Ribeiro, RF., Silva-Sousa, YTC. and Gomes, EA. 2016. Fracture strength of weakened anterior teeth Associated todifferent reconstructive techniques. *Braz Dent J.,* 27(5):556-561.

Fragou, T., Tortopidis, D., Kontonasaki, E., Evangelinaki, E., Ioannidis, K., Petridis, H. *et al*. 2012. The effect of ferrule on the fracture mode of endodontically treated canines restored with fibre posts and metal-ceramic or all-ceramic crowns. *Journal of Dentistry,* 40:276-285.

Fukui, Y., Komada, W., Yoshida, K., Otake, S., Okada, D. and Miura, H. 2009. Effect of Reinforcement with resin composite on fracture strength of structurally compromised roots. *Dental Materials Journal,* 28(5):602-609.

Gehrcke, V., Oliveira, M., Aarestrup, F., Prado, M., Lima, CO. and Campos, CN. 2017. Fracture strength of flared root canals restored with different post systems. *Eur Endod J.,* 2:24.

Giovani, AR., Vansan, LP., Souza Neto MD de and Paulino, SM. 2009. In vitro fracture resistance of glass-fiber and cast metal posts with different lengths. J *Prosthet Dent.,* 101(3):183-188.

Gomes, EA., Gueleri, DB., Silva SRC da, Ribeiro, RF. and Silva-Sousa, YTC. 2015. Three-dimensional finite element analysis ofendodontically treated teeth with weakened radicular walls restored with different protocols. *J Prosthet Dent.,* 114:383-389.

Gomes, GM., Monte-Alto, RV., Santos, GO., Fai, CK., Loguercio, AD., Gomes, OMM. *et at*. 2016. Use of a direct anatomic post in a flared root canal: A three-year follow-up. *Operative Dentistry*, ;41(1):E23-E28.

Grandini, S., Sapio, S. and Simonetti, M. 2003. Use of anatomic post and core for reconstructing an endodontically treated tooth: a case report. *J Adhes Dent.,* 5(3):243-247.

Jain, M. and Vinayak, V. 2011. Post-endodontic rehabilitation using glass fiber non metallic posts: A review. *Indian J Stomatol.,* 2(2):117-119.

K1vanç, BH., Alaçam, T., UlusoyÖIA, GençÖ and Görgül, G. 2009. Fracture resistance of thin-walled roots restored with different posts systems. *International Endodontic Journal,* 42:997-1003.

Laxe, LAC., Andrade, Filho H de, Mendes, LM. and Pinto, BD. 2011. Pinos fibrorresinosos: revisão de suas propriedades fisicas e mecânicas. *FULL Dentistry in Science,* 6(2):190-198.

Li, Q., Xu, B., Wang, Y. and Cai, Y. 2011. Effects of auxiliary fiber posts on endodontically treated teeth with flared canals. *Operative Dentistry*, 36(4):380-389.

Liang, BM., Chen, YM., Wu, X., Yip, KH. and Smales, RJ. 2007. Fracture resistance of roots with thin walls restored using an intermediate resin composite layer placed between the dentin and a cast metal post. *Eur J Prosthodont Dent*., mar;15(1):19-22.

Makade, CS., Meshram, GK., Warhadpande, M. and Patil, PG.2011. A comparative evaluation of fracture resistance of endodontically treated teeth restored with different post core systems – an in vitro study. *J Adv Prosthodont.,* 3:90-95.

Marchionatti, AME., Wandscher, VF., Rippe, MP., Kaiser, OB. and Valandro, LF. 2017. Clinical performance and failure modes of pulplees teeth restored with posts: A systematic Review. *Braz Oral Res.,* 31:e24.

Martinez-Insua, A., Da Silva, L., Rilo, B. and Santana, U. 1998. Comparison of the fracture resistances of pulpless teeth restored with cast post and core or carbon-fiber post with a composite core. *J Prosthetdent.,* 80(5):527-532.

Mattos, CMA., Las Casas, EB., Dutra, IGR., Sousa, HA., Guerra, SMG. 2012. Numerical analysis of the biomechanical behaviour of a weakened root after adhesive reconstruction and post-core rehabilitation. *Journal of Dentitry,* 40:423-432.

Mireku, AS., Romberg, E., Fouad, AF. and Arola, D. 2010. Vertical fracture of root filled teeth restored with posts: the effects of patient age and dentine thickness. *International Endodontic Journal*, 43:218-225.

Mitsui, FHO., Marchi, GM., Pimenta, LAF. and Ferraresi, PM. 2004. In vitro study of fracture resistance of bovine roots using different intraradicular post systems. *Quintessence Int.,* 35(8):612-616.

Resende, LCM., Araújo, TP., Resende, AB., Cavalcanti, YW. de Almeida LFD, Padilha WWN *et al.,* 2017. Fractureresistenceofedodonticallytreatedteethrestoredwithd ifferenttypesofintracanal posts. *Pesq Bras Odontoped Clin Integr.,* 17(1):e2995.

Salam, SNA., Banerjee, A., Mannocci, F., Pilecki, P. and Watson, TF. 2006. Cyclic loading of endodontically treated teeth restored with glass fibre and titanium alloy posts: Fracture resistance and failure modes. *Eur J Prosthodont Rest Dent.,* 14(3):98-104.

Santos, AFV., Meira, JBC., Tanaka, CB., Xavier, TA., Ballester, RY., Lima, RG. *et al.* 2010. Can Fiber increase root stresses and reduce fracture. *J Dent Res.,* 89(6):587-591.

Silva, GR., Santos-Filho, PCF., Simamoto- Júnior, PC., Martins, LRM., Mota, AS. and Soares, CJ. 2011. Effect of post type and restorative techniques on the strain and fracture resistance of flared incisor roots. *Braz Dent J.,* 22(3):230-237.

Sirimai, S., Riis, DN. and Morgano, SM. 1999. An in vitro study of the fracture resistance and the incidence of vertical root fracture of pulpless teeth restored with six post-and-core systems. *J Prosthet Dent.,* mar;81(3):262-269.

Teixeira, D., Andrade MAC de, Baratieri, LN., Monteiro-Junior, S. 2005. Influence of the number of resin-fiber posts on the fracture resistance of composite cores in roots with flared canals. *International Journal of Brazilian Dentistry,* out/dez;4(1):323-329.

Theodospoulou, JN. and Chochlidakis, KM. 2009. A Systematic review of dowel (post) and core materials and systems. *Journal of Prosthodontics,* 18:464-472.

Torabi, K. and Fattahi, F. 2009. Fracture resistance of endodontically treated teeth restored by different FRC posts: An in vitro study. *Indian J Dent Res.,* 20(3):282-287.

Torres-Sánches, C., Montoya-Salazar, V., Córdoba, P., Vélez C., Gúzman-Duran, A., Guierrez-Pérez, JL. *et al*. 2013. Fracture resistance of endodontically treated teeth restored with glass fiber reinforced posts and cast gold post and cores cemented with three cements. *J Prosthet Dent.,* 110:127-133.

Varvara, G., Perinetti, G., Di Lorio, D., Murmura, G. and Caputi, S. 2007. In vitro evaluation of fracture resistance and failure mode of internally restored endodontically treated maxillary incisor with differing Heights of residual dentin. *J Prosthet Dent.,* 98(5):365-372.

Wu, X., Chan, AT., Chen, YM., Yip, KH. and Smales, RJ. 2007. Effectiveness and dentin bond strengths of two materials for reinforcing thin-walled roots. *Dent Mater.,* apr;23(4)479-485.

Xiong, Y., Huang, SH., Shinno, Y., Furuya, Y., Imazato, S., Fok, A. *et al.* 2015. The use of a fiber sleeve to improve fracture strength of pulpless teeth with flared root canals. *Dent Mater.,* 31:1427-1434.

Zhou, L. and Wang, Q. 2013. Comparison of Fracture Resistance between Cast Posts and Fiber Posts: A Meta-analysis of Literature. *J Endod.,* 39(01):11–15.

Zicardi, F., Van Meerbeek, B., Scotti, R. and Naerti, I. 2013. Effect of ferrule and post placement on fracture resistance of endodontically treated teeth after fatigue loading. *Journal of Dentistry,* 41:207-215.

Zogheib, LV., Pereira, JR., Valle AL do, Oliveira JA de and Pegoraro, LF. 2008. Fracture resistance of weakened roots restored with composite resin and glass fiber posts. *Braz Dent J.,* 19(4):329-333.

Özcan, M. and Valandro, LF. 2009. Fracture strength of endodontically-treated teeth restored with post and cores and composite cores only. *Operative Dentistry,* 34(4):429-436.

Özdemir, E., Lin, WS., Erkut, S. and Tuncer, AH. 2012. Interfacial evaluation of endodontically treated teeth restored with selected adhesive materials and glass fiber posts: An SEM analysis. *Journal of Dental Sciences,* 1-8.

****